Research Article

Organic Fertilizer Use Does Not Reduce Crop Revenue: Evidence from Rice Farmers in Indo-Gangetic Plains, India

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India's Indo-Gangetic Plain (IGP) area is facing the implications of inorganic fertilizer overuse for the cultivation of cereals. Groundwater contamination, atmospheric pollution, and the decline in soil health are the major concerns there. Against this backdrop, this article analyses the organic fertilizer adoption by rice farmers along with the influencing factors. Primary data pertaining to 400 farmers cultivating rice in the IGP area is used for analysis. The effect of adopting organic fertilizers on crop revenue is an important question not dealt with previously in the literature. While Probit analysis was used to analyze the adoption of organic fertilizers, the Regression Adjustment model, a useful impact assessment method, was applied to find out the effect on crop revenue. The analysis suggested that among the farmers surveyed, a mere 32 per cent adopted organic fertilizers. Further, the significant factors influencing their adoption are age, membership in farmer organizations, education, and a positive perception of organic fertilizer. The crop revenue has not declined significantly with the adoption of organic fertilizers. The results highlight the significance of creating better awareness of this group of fertilizers, for which traditional knowledge can be tapped to maneuver farmers' perceptions and increase adoption.

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Introduction

Fertilizers are accepted globally as crucial input for achieving the targets of higher food production and food security[1]. Literature credits nitrogen fertilizers for contributing at least 40 per cent to the increment in global food production per capita[2]. The direct effect of N fertilizers on food production has

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made it one of the favourite fertilizers across the world. Its consumption has risen several times from the consumption level of the 1960s[3]. The cause of concern, however, is that, with higher N consumption in agriculture, more of the unutilized N enters the environment by nitrification & denitrification, as well as leaching and volatilization[4]. Since the crops effectively use only 30-50 per cent of the applied chemical fertilizers, consistent use of higher levels of such fertilizers will result in issues like soil and water contamination, greenhouse gas emissions, etc[5]. Further, it is also detrimental to the health of the soil and soil microbes[6], leading to a decline in soil organic matter and faster acidification of soil[7]. Hence the recent thrust is to identify strategies to reduce chemical fertilizer use without hampering food security[8].

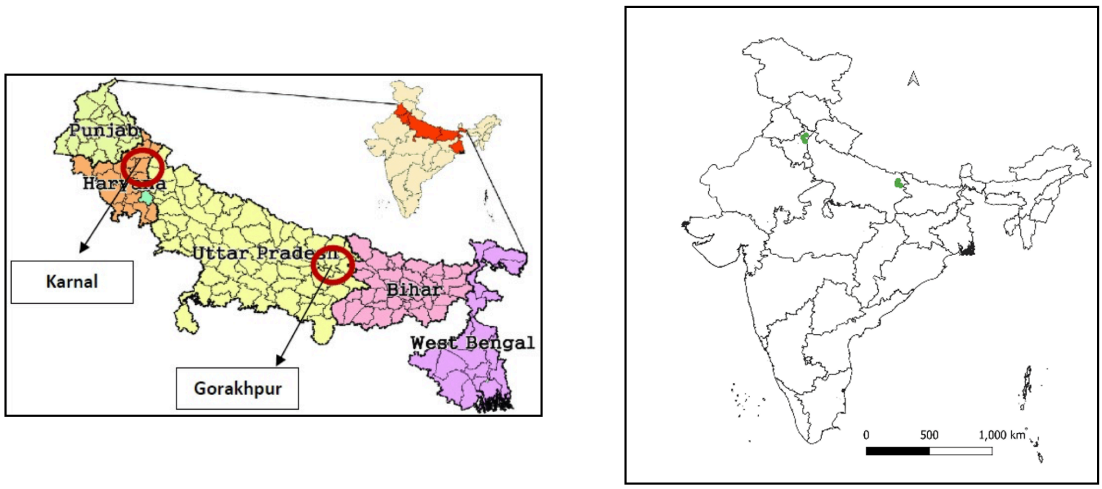
At present, India is one of the largest chemical fertilizer-consuming nations. In 2018, India used about 17.6 million tonnes (Mt) of Nitrogen (N), 2.7 Mt of Potash (K), and 6.9 Mt of Phosphate (P) fertilizers[9]. Fertilizer consumption has increased in India as a result of the green revolution. The use of chemical fertilizers along with other inputs has helped India to raise its food grain production during the 1970s and 1980s[10]. The green revolution was mainly cereal-centric, and pockets like Indo-Gangetic Plains (IGP) have embraced the technologies rapidly for higher cereal production[11]. Though such rapid adoption of higher inputs contributes immensely to satisfying the country's rising number of people, recently, the environmental effects of indiscriminate use of fertilizer have gained the attention of the government, policymakers, and researchers[12]. It is high for India to embrace strategies that help increase food production without hampering the environmental quality. Organic fertilizers are identified as one of the key interventions[13].

Though Indian agriculture has traditionally depended on organic fertilizers/manures for agricultural production, its use has declined since the green revolution. Considering the benefits of using organic fertilizers like improvement in soil structure, soil microbial diversity, and soil properties which will ultimately lead to better crop production, using organic fertilizers concurrently with decreased amounts of inorganic fertilizers can lead to improved agricultural Sustainability in the future[14]. However, a major concern is India's low farm-level adoption rate due to multiple constraints[15]. Farmers perceive that organic fertilizer use is an additional expenditure that may reduce their crop revenue. Among the other factors, farmers' risk aptitude, farmer and farm-specific characteristics, profit expectations, policies in effect, and marketing channels are crucial in determining organic fertilizer adoption[7]. The data generated through a rural household survey from the IGP of India is used to test the factor determining

organic fertilizer adoption empirically. Data from the rice farmers are used, as the rice-wheat cropping system is popular there. Rice farming in IGP has followed an input-intensive mode since the green revolution. Thus, analyzing the farmers' perceptions and choices related to fertilizers becomes relevant. We examine organic fertilizer adoption and identify the possible factors influencing their decision. Further, the effect of organic fertilizer adoption on crop revenue is also tested.

Data and methodology

The insights and data required for this study were collected from the IGP from March to June 2020. Information was gathered from a total of 400 rice-cultivating farmers. We followed a multi-stage sampling technique to arrive at our sampling units from the IGP region. In the first stage, from the entire districts falling in different transect zones of the IGP, we identified Karnal (from the Upper Gangetic Plains) and Gorakhpur (from the Middle Gangetic plains) randomly (Fig. 1). In the next stage, we identified one block from each district (Karnal block and Bansgaon block from Karnal and Gorakhpur districts respectively) considering the higher area under rice. Next, 4 villages, namely Kachhwa, Kalampura, Landhora, and Sangohi, were randomly selected from the Karnal block; from the Bansgaon block, we identified Dhobauli, Bharohia, Basauli, and Siswan). Finally, 50 rice farmers were selected randomly from each of the eight villages identified. Thus we could collect data from 400 rice farmers, 32 per cent of which adopted organic fertilizers. We used a structured schedule for the data collection on aspects including the demographic & household characteristics, along with farm characteristics and the farming practices followed. We also collect information on farmers' risk preferences and perceptions of organic fertilizers.



(a) (b)

Figure 1. Map of the study area (Indo-Gangetic Plains region of India): (a) Sample districts from the IGP selected for the primary survey; (b) Location of the sample villages

Adopting organic fertilizers would be a dichotomous variable with a value of '1' if the farmer applied organic fertilizers and '0' otherwise. We used a probit regression model to determine the factors influencing organic fertilizer adoption. The socioeconomic variables, farm-related variables, and the farmers' perceptions of organic fertilizers are included in the model. To examine the effect of using organic fertilizer on crop revenue, we use the Regression adjustment (RA) model. RA fits separate regression models of the outcome on a set of covariates for each treatment level and computes the averages of the predicted outcomes for each subject and treatment level. RA estimators use the contrasts of the averages of treatment-specific predicted outcomes to estimate treatment effects.

Results and Discussion

Organic fertilizer use in India

Farmers in India use a wide range of organic fertilizer products, from farmyard manure/ manure to branded organic fertilizer products by industry. However, the data on organic fertilizer consumption is not available in a compiled form at the national and state levels owing to the difficulties in accessing the data. The data on manure use in India is available, and the nitrogen content in the manure used in Indian agriculture is given in Fig. 2 as available from the FAOSTAT database[16]. It has only increased marginally

from about 1.2 million tonnes in 1960 to 2.3 million in 2019. During the same period, chemical fertilizer consumption has increased manifold. The consumption of manure and chemical fertilizers in rice cultivation in the major states of India are compiled from the cost of cultivation data released by the Ministry of Agriculture and the government of India[17] and are given in Fig. 3 and Fig. 4, respectively. When we compare the two figures, it is clear that while chemical fertilizer use increased in most states between 2009 and 2018, manure use decreased in several states. Interestingly, manure use in the country's major rice-producing states has decreased, which is worth investigating. The government has also recently emphasized using organic fertilizers because they are crucial in maintaining soil health.

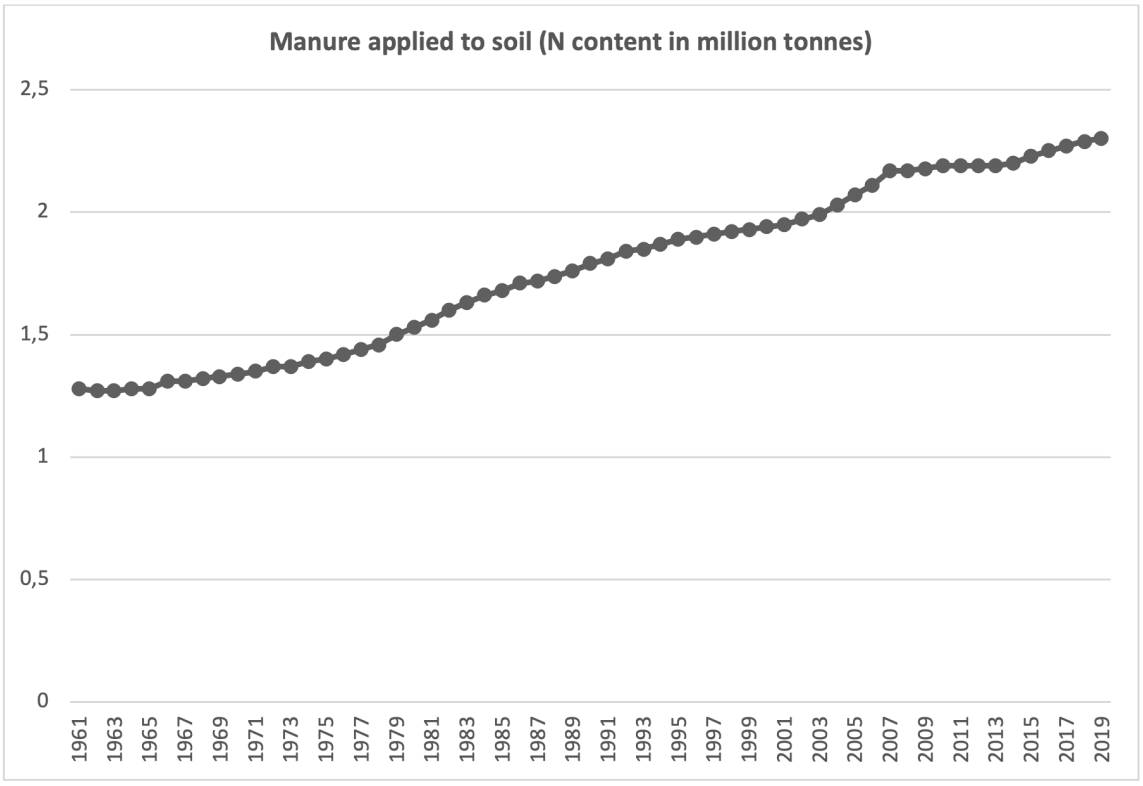


Figure 2. Nitrogen content of the manure applied to soil (million tonnes)

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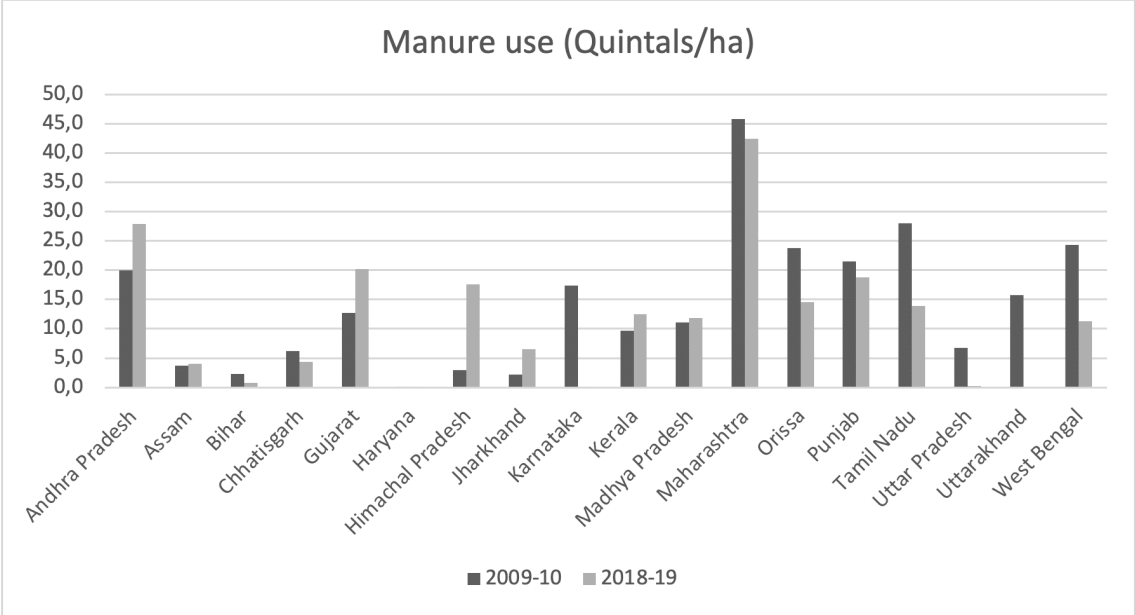

Figure 3. Manure use across states for rice cultivation (quintals/ha)

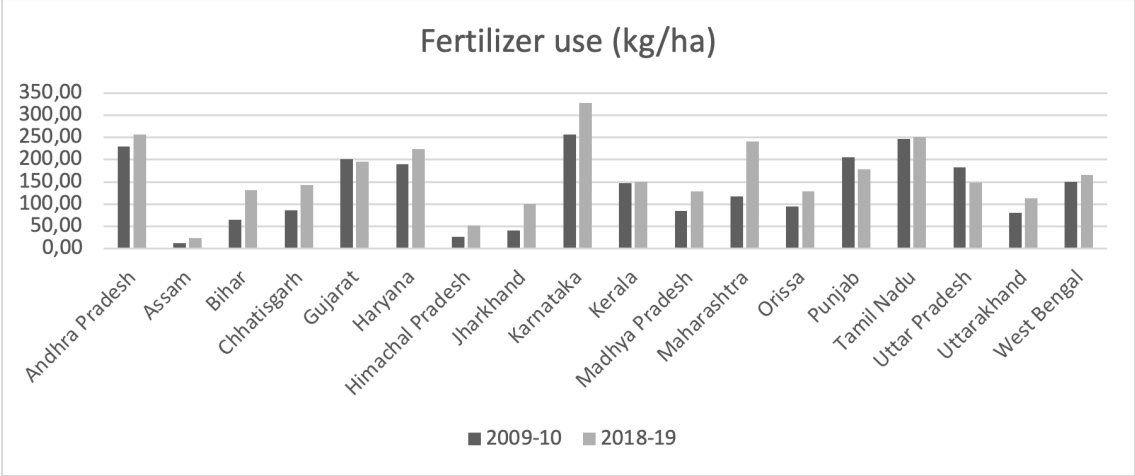

Figure 4. Fertilizer use across states for rice cultivation (kg/ha)

Summary statistics of the variables

The summary statistics of the important variables used for analysis are given in table 1, along with the mean comparison for adopters and non-adopters of organic fertilizers. All the respondents of our primary survey used chemical fertilizers. However, the statistics were drastically different for organic fertilizers, as only 32 percent used them. Respondents from the study area spent five times more on

chemical fertilizers than organic ones. The respondents' average risk score of 3.38 indicated a higher risk preference and attitude to embracing improved agricultural practices. About 17% of the respondents got the opportunity to attend training on organic fertilizers, and nearly 26 per cent had membership in farmers' organizations. Adopters and non-adopters differed significantly in farming experience, education, age, tenancy status, and membership organizations. Meanwhile, no such difference could be observed in the level of chemical fertilizer use. This points the adoption of organic fertilizers does not impact the chemical fertilizer application.

Variables	Non-adopters (mean)	Adopters (mean)	Mean	Mean Difference
Gender (female=0, male=1)	0.963	0.945	0.96	0.018
Age (in years)	50.346	43.031	48.01	7.314***
Marginalized group (yes=1, no=0)	0.114	0.055	0.10	0.059*
Years of education	6.842	9.969	7.84	-3.127***
Years of experience in agriculture	31.879	24.664	29.57	7.215***
Tenancy status (yes=1, no=0)	0.272	0.148	0.23	0.124***
Soil health card (yes=1, no=0)	0.426	0.695	0.51	-0.269***
Member in farmer group (yes=1, no=0)	0.114	0.586	0.27	-0.472***
Organic fertilizer training (yes=1, no=0)	0.007	0.523	0.17	-0.516***
Farm to home distance (near=1, far=0)	0.772	0.813	0.79	-0.04
Crop area (hectares)	1.256	2.457	1.64	-1.201***
Chemical fertilizer use (kg)	186.973	197.078	190.21	-10.105

Table 1. Household socioeconomic characteristics by status of adoption

*Note: ***, ** and * represent significance levels at 1%, 5% and 10%, respectively, for the mean difference from t-test*

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Farmers' perception of organic fertilizers

Table 2 presents the farmers' perception of organic fertilizers. The data for analyzing the perception of adopters and non-adopters towards organic fertilizers are collected on a 5-point Likert scale, and the mean values are compared using a t-test. There was a significant difference in the perception of the two category farmers towards organic fertilizers. The non-adopters of organic fertilizers perceived that the use of organic fertilizers would reduce crop yield and increase pest and disease incidence but will not increase output price and market acceptance. The non-adopters were also unsatisfied with the support they received regarding subsidies. They demanded sale contracts and certification of their products for using organic fertilizers, besides better extension support from the agencies. Most farmers prefer not to apply organic fertilizers as their effect is not visible immediately on the crop. The extension system can play a crucial role in influencing the farmers' perception of organic fertilizers. Besides, the farmers should be educated on the importance of organic fertilizers for sustained soil health and the right means of handling and storing organic fertilizers.

Variables	Mean	Non-adopters (mean)	Adopters (mean)	Mean Difference
Yield will decrease (5-point scale: 1=strongly agree; 5=strongly disagree)	3.08	2.71	3.867	-1.158***
Better output price (5-point scale: 1=strongly agree; 5=strongly disagree)	2.53	2.632	2.305	0.328***
Higher pest and disease incidence (5-point scale: 1=strongly agree; 5=strongly disagree)	3.08	2.801	3.656	-0.855***
Improved market acceptance (5-point scale: 1=strongly agree; 5=strongly disagree)	2.64	2.801	2.289	0.512***
I will adopt if I get sale contracts (5-point scale: 1=strongly agree; 5=strongly disagree)	2.63	2.441	3.023	-0.582***
I will adopt if my produced is certified (5-point scale: 1=strongly agree; 5=strongly disagree)	2.40	2.037	3.172	-1.135***
I will adopt if I get subsidies (5-point scale: 1=strongly agree; 5=strongly disagree)	2.18	1.261	4.141	-2.880***
I require better extension services (5-point scale: 1=strongly agree; 5=strongly disagree)	2.04	1.46	3.281	-1.822***

Table 2. Farmers' perception on organic fertilizers use

*Note: ***, ** and * represent significance levels at 1%, 5% and 10%, respectively, for the mean difference from t-test*

Covariates of adoption of organic fertilizers

The results of the probit analysis to determine the factors affecting the adoption of organic fertilizer are given in Table 3. Among the variables included in the model, membership in farm organizations, soil fertility, tenancy status, age, the distance between farm to home, education, and chemical fertilizer use significantly affect organic fertilizer adoption. The other factors influencing the adoption include the

farmers' perception of how organic fertilizers affect yield, acceptance in the market, complexities in organic certification, and linkage with the extension system. The farmers perceiving no yield reduction and no increase in pests and disease attacks due to organic fertilizer use showed a better tendency to adopt. Farmer organization membership and training participation also positively affected the adoption. Educated farmers belonging to the younger age group, closely working with farmer organizations, attending training, and perceiving positively on organic fertilizers showed a better tendency to use them.

On the other hand, those following intensive chemical fertilizer application showed a lower probability of adopting organic fertilizers. Younger and educated farmers should be encouraged to participate in organic fertilizer training. They may be empowered to act as progressive farmers who can disseminate knowledge on how, when, and why to apply these. In short, to improve organic fertilizer use, the farmer groups may be targeted and trained.

Variables	Coefficient	Marginal effect
Gender (female=0, male=1)	-1.591 (2.382)	-0.029
Age (in years)	-0.405* (0.218)	-0.007
Marginalized group (yes=1, no=0)	5.335 (3.483)	0.077
Years of education	0.842* (0.452)	0.015
Years of experience in agriculture	0.093 (0.108)	0.002
Tenancy status (yes=1, no=0)	-5.144* (2.945)	-0.041
Soil health card (yes=1, no=0)	-0.961 (1.347)	-0.016
Member in farmer group (yes=1, no=0)	8.086** (3.873)	0.120
Organic fertilizer training (yes=1, no=0)	7.354 (7.595)	0.127
Farm to home distance (near=1, far=0)	3.620* (2.110)	0.033
Soil fertility status	-1.224* (0.730)	-0.022
Chemical fertilizer use	-0.036* (0.020)	-0.001
Reduction in crop yield	2.859** (1.370)	0.051
Increase in output price	-1.164 (0.810)	-0.021
Higher pest and disease incidence	2.539 (2.404)	0.045
Market acceptance	-6.123** (3.048)	-0.109
Sale contracts	-0.533 (0.587)	-0.009
Product certification	3.023** (1.450)	0.054
Subsidies	6.448**(3.063)	0.115
Constant	-1.208 (4.793)	

Table 3. Probit estimates for determinants of adoption of organic fertilizers

*Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1*

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Organic fertilizer adoption and its effect on crop revenue

The results of the effect of adopting organic fertilizers on revenue from rice cultivation were estimated using the Regression Adjustment model (Table 4). As per our results, we could not observe any effect on crop revenue due to adopting organic fertilizers. The coefficient indicating the average treatment effect on the treated was insignificant, as the crop produced by all the farmers currently receives comparable market prices. However, we do not claim that organic products receive the same price as others. However, the requirement for enjoying price advantage is using organic inputs exclusively, which is different in our case. We could also identify through focus group discussions in the study area that the key constraint acting against organic fertilizer adoption is the farmers' belief in yield reduction due to using organic fertilizers. Farmers commonly think of substituting organic fertilizers instead of chemical fertilizers, but in the IGP region, the initial step can be to use both conjunctively. To ensure a sustainable future, the strategy is to tap those farmers who are not adopting organic fertilizers for fear of losing revenue. Besides, the positive impact of organic fertilizer use on crop yields and revenue may be hidden in the short term. Farmers using organic fertilizers thus must be encouraged to continue that long term to enjoy maximum benefits.

Average treatment effect on the treated (ATET)	Coefficient	Robust Std. Err.	z	P>|z|					
					Organic farming use	−31944.8	21329.85	-1.5	0.134

Table 4. Effect of organic fertilizer adoption on the crop revenue

Conclusion

Utilizing data collected through a primary field survey of paddy cultivators in the IGP region of India, we explored the use of organic fertilizers, factors determining organic fertilizer adoption, and the effect of organic fertilizers on crop revenue. We contribute to the literature on organic fertilizer use by farmers by linking their desire for better income, prices received in the market, socioeconomic variables, regulatory regimes, and perception of technology benefits. The study pointed out the lower adoption of organic fertilizers in the study area and the factors that significantly contribute to adoption. These findings can

help formulate effective policies to improve its usage. The crop revenue was not affected negatively due to organic fertilizer adoption. Further, the major determinants of adoption were age, education, farmer organization membership, and the perception of organic fertilizers. Our findings also have policy implications, primarily related to the plan of soil nutrient management in the IGP. First, the government should promote group farming decisions suitable to the local soil requirements. The farmers with lesser education, higher age, and even training-deprived farmers could also benefit from organic fertilizers. Second, as the positive perception towards organic fertilizers has a significant effect on their adoption and usage level, the government should ensure more efforts to popularize the technology's benefits, including traditional knowledge. Farmers may need help with organic fertilizers: their benefits could only be realized in the long term. The extension departments can come into the act here to make the farmers believe that applying organic fertilizers for a longer term would pay them immense benefits. Finally, future research in this line can generate empirical findings from varying locations to check whether our findings hold their ground there.

Statements and Declarations

Acknowledgments

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Conflicts of Interest

The authors declare no conflict of interest.

Authors' contributions

Conceptualization, PKV and AS; methodology, PKV and AS; software, PKV; validation, PKV and AS..; formal analysis, PKV; writing—original draft preparation, PKV; writing— review and editing, PKV and AS; supervision, AS; funding acquisition, AS.

Ethics

The study involving human participants was reviewed and approved by the Resource Planning and Monitoring (RPM) Committee, ICAR-Indian Agricultural Research Institute. The participants provided their verbal informed consent to participate in this study, as written consent was not feasible for all participants in the rural context; this procedure was approved by the RPM committee. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Data Availability

The datasets generated and analyzed during the current study are not publicly available due to privacy concerns related to personal information of the participants. However, anonymized data may be made available from the corresponding author on reasonable request.

Reporting Guidelines

The authors have prepared this manuscript in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

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Declarations

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